Reliable, Low Cost ISS Flight Research Instruments
Available Through the Commercial Space Center Program

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Introduction

This paper describes hardware that has been developed by NASA Commercial Space Centers and their partners for experimentation on-board the International Space Station. Consortium building being a central element of the CSC program, this information may stimulate others to join with the CSCs in carrying out research on the International Space Station (ISS).

The following paragraphs first present a brief background of the CSC program describing its operating principles and including all the names and contacts for the centers. The background section is followed by a flight hardware summary that presents hardware technical characteristics and capabilities. The last section summarizes program status.

Background

The CSCs are funded through NASA Code U, the Office of Biological and Physical Research. The centers are managed by the Space Product Development office located at the Marshall Space Flight Center in Huntsville Alabama.

The primary mission of the CSCs is to build consortia, especially with industry, for the purpose of developing goods and services associated with space that produce a return on investment for the participants.

The 17 CSCs are listed in Table 1. As the titles indicate, CSC activities span a wide range of sciences, technologies, and the infrastructure necessary to conduct research in space. 163 industry affiliates are part of CSC consortia. CSC cumulative space experience includes 354 mid-deck locker equivalents on the STS and 3 hardware packages presently on station. The CSCs have developed the expertise to design, build and flight integrate their hardware. This organic capability results in reduced program costs and lead times producing a return on investment in the shortest possible time.

Table 1. COMMERCIAL SPACE CENTERS

BIOTECHNOLOGY

Bioserve Space Technologies
Center for Biophysical Science and Engineering
Consortium for Materials Development in Space
Wisconsin Center for Space Automation and Robotics
ProVision Technologies
Medical Informatics and Technology Application Center
Food Technology Commercial Technology Space Center
Environmental Systems Commercial Space Technology

CHEMISTRY

Center for Advanced Microgravity Materials

INFRASTRUCTURE

Center for Space Power
Space Communications Technology Center
Satellite and Hybrid Communications Networks
Commercial Space Center for Engineering
Center for Space Power and Advanced Electronics

ENGINEERING SCIENCES

Center for Commercial Applications of Combustion in Space
Solidification Design Center
Space Vacuum Epitaxy Center

Flight Hardware

Table 2 is a list of CSCs and some of their associated flight hardware. Several of these are described below. However, they represent only a small fraction of the overall CSC capability. See the NASA commercialization web site at URL <Commercialization.NASA.Gov> for more complete information.

Bioserve Space Technologies' Commercial Generic Bioprocessing Apparatus - The Commercial Generic Bioprocessing Apparatus (CGBA) shown in Figure 1 is a single-locker, temperature-conditioned enclosure that can accommodate up to 72 separate biological samples. The entire system supports the growth of biological material in space while measuring environmental and sample-specific data. Each CGBA locker contains nine Group Activation Packs (GAPs), each of which contain eight Fluid Processing Apparatus (FPAs). Activation of the FPA's was achieved by using a hand-crank on previous shuttle missions. The ISS version is automated, eliminating crew interaction with the sample containers.

Figure1. CGBA front and top views

Table 2. CSC Flight Hardware

BioServe Space Technologies

Commercial Generic Bioprocessing Apparatus (CGBA) bioprocessing

<u>Hardware Specifications</u>

- Isothermal Containment Module (ICM) version 2 (v2) and version 3 (v3)
- Temperature controlled incubator (4°C - 37°C)
- Five-sided temperature control to reduce gradients (v2)
- Eight individually temperature-controlled areas (v3)
- Total experiment volume up to 27 liters (v2) and 10 liters (v3)
- Accelerometer – based launch detection system allows programmable experiment initiation
- Data, video, and telemetry capabilities
- Telescience operations

Plant Generic Bioprocessing Apparatus (PGBA) plant growth

<u>Hardware Specifications</u>

- Space flight plant growth chamber
- Nutrient delivery system
- 6.35 cm rooting depth
- 25 cm x 30cm x 25cm aerial tissue volume
- Holds up to 120 plants
- Provides temperature, humidity, CO_2 and lighting control
- Data acquisition for monitoring plant growth and performance
- Video downlink
- Telescience operations

Space Automated Bioprocessing Laboratory (SABL) bioprocessing

<u>Hardware Specifications</u>

SABL is currently under development, but is a multifunctional, multipurpose piece of hardware that can incorporate all of the configurations of BioServe's CGBA. When completed, the payload may use up to 4 lockers on the ISS express rack. The payload will be able to house and run the experiment and conduct certain analyses while in orbit. SABL will also be in the rear-breathing configuration that will be required for all ISS payloads.

Commercial Biomedical Testing Module (CBTM) mammal enclosure

<u>Hardware Specifications</u>

Commercial Biomedical Testing Module – is a research program at BioServe developed for biotech and pharmaceutical companies interested in drug development and testing that utilizes animals. BioServe has 15 years of expertise in disuse animal research studies particularly with mice. Companies capitalize on that expertise in this program. The program uses the Animal Enclosure Modules (AEMs) built and currently managed by NASA Ames.

Wisconsin Center for Space Automation and Robotics

Advanced Astroculture (ADVASC) plant growth

<u>Hardware Specifications</u>

<u>Growing space</u>
Volume: 18,217 cm^3
Shoot height: 33 cm
Root height: 4 cm

<u>Chamber environment</u>
Temperature: 17 - 45 ^{o}C ± 0.5 ^{o}C
Humidity: 40 - 95 %RH ± 3 %RH
Light Intensity: 0 - 500 mmol/m^2/s (LED Red)
0 - 70 mmol/m^2/s (LED Blue)
CO2: 400 - 2000 ppm
Ethylene: Active ethylene removal capability
Condensation recovery rate: Max. 0.9 l/day

Commercial Plant Biotechnology Facility (CPBF) plant growth

Hardware Specifications

Growing space
Volume: 109,935 cm^3
Shoot height: 43 cm
Root height: 5 cm (changeable)

Chamber environment
Temperature: 15 - 45 ^{o}C ± 0.5 ^{o}C
Humidity: 40 - 95 %RH ± 3 %RH
Light Intensity: 0 - 900 mmol/m^2/s (LED Red)
0 - 120 mmol/m^2/s (LED Blue)
0 - 470 mmol/m^2/s (Fluorescent)

CO2: 300 - 2000 ppm
Ethylene: Active ethylene removal capability
Condensation recovery rate: Max. 2.0 l/day

Center for Biophysical Sciences and Engineering

High Density Protein Crystal Growth (HDPCG) protein crystal growth

Hardware Specifications

- HDPCG provides 1008 PCG samples within a single middeck style incubator such as CRIM-M and NGTC (shown installed in a CRIM-M)
- Uses vapor diffusion method for PCG
- Future plans include the addition of batch temperature and liquid/liquid growth methods
- Easily accessible by Space Station crew members
- Sample volumes consistent with previous VDA type experiment each well holds up to 40 microliters
- Four interchangeable tray assemblies
- Flew for the first time on 6A

Video Control and Monitoring System (VCMS) PCG monitoring

Hardware Specifications

- Real time observation of one HDPCG Tray from the ground

- It has the versatility of interchanging the HDPCG Trays when scheduled or requested
- It evaluates protein crystal size, location, and potential for x-ray data collection
- The VCMS video camera system has both automatic and manual command capabilities for X and Y translation. This system installs within a single middeck style incubator such as CRIM-M and NGTC (shown installed in a CRIM-M)
- The VCMS Controller is located in the EXPRESS Rack Powered ISIS Drawer where it mounts to a modified baseplate

Commercial Refrigerator Incubator Module-Modified (CRIM-M)

Hardware Specifications

- Present incubator in use for PCG & other temperature controlled payloads
- As of August 2001, CRIM has flown 50 times ISS Communications (Health & Status)
- Designed with a single middeck locker profile
- Back-plate Captive Fasteners installed for quick transfer to ISS from Shuttle
- Fully qualified as space flight hardware
- Requires only a mission specific Phase III Delta Safety Review
- Large front swing-down door allows quick access to the experiment
- Accommodates experiments of up to 0.66 ft3 (H6.69 in. x W10.188 in. x D16.50 in., +/-0.030 in.)
- Accommodates experiments of up to 28.0 lbs.
- Provides thermal control from 4 ^{o}C to 40° C
- Provides up to 0.85 A (derated) continuous current at nominal STS power voltage (24 to 32 VDC) from the CRIM power buss

Center for Commercial Applications of Combustion in Space

Space Dynamically Responding Ultrasonic Matrix System (Space-DRUMS™) combustion synthesis

Hardware Specifications

The Development of Organic Materials for Electroluminescence (DOME) facility in collaboration with the Optical Sciences Center at the University of Arizona. This payload will process organic materials using vapor phase deposition in microgravity aboard the International Space Station. The facility is housed in a standard single Express Rack locker, which is approximately 2 cubic feet in volume. DOME will have the ability to perform single- or multi-layer depositions for the production of OLEDs and, possibly, other electroluminescent devices in the future. The payload will consist of five processing chambers that will be able to process source materials up to 450°C. It will access the vacuum exhaust system (VES), vacuum resource system (VRS) and nitrogen system (GN_2) aboard ISS.

Center for Advanced Microgravity Materials Processing

Zeolite Crystal Growth (ZCG) solution crystal growth

Hardware Specifications

IZECS/ZCG (Improved Zeolite Experiment Control/Zeolite Crystal Growth) Unit: A complete redundant control system is available to provide data acquisition, computer control and telemetry for four furnaces. The ZCG facility is being designed to grow into four independent furnaces controlled by IZECS. These can be operated separately or all at once. IZECS provides monitoring of critical parameters, data logging, safety monitoring, ground control and crew interfacing. It also contains the power management solid-state drivers and switches for the ZCG-FU furnace (nineteen individually controlled furnace tubes, operational range 88-200 C). Each of the other three furnaces will have their own power management modules and these are controlled by means of a sense and control signal cable connected to IZECS. IZECS interfaces with the ISS EXPRESS Rack Interface Controller (RIC) via Ethernet communication link. This permits a two-way command and data link with ground based stations for data downloading and ground commanding. The on board Portable Computer System (PCS) is available to ISS crew for high level local trouble-shooting and special commanding of IZECS. Normal crew interfacing is available from the IZECS front panel. The IZECS unit will be able to control the existing furnace (ZCG/FU) as well as three other furnace modules to be built for the ISS flights. (ZCG/HTF- High Temperature Furnace-88-350 C, ZCG/QCF - Quench Cooled Furnace –250 to 25 C in four minutes, and ZCG/HVF-High Volume Furnace total solution volume ~ l liter.) Flight qualified, ground control units (GCEL) are also available for the IZECS and all furnace configurations.

Autoclaves Autoclaves have been designed to handle caustic solutions (pH7 – 13). They can mix two separate solutions on orbit either manually, or by ground command. Total volumes vary from 10 ml to 216 ml and the solutions can be mixed a variety of different ways. These autoclaves are designed and approved to pressures from 14.7 psia to 2500 psia.

Solidification Design Center

Vulcan acoustic levitation furnace

Hardware Specifications

Vulcan-TP/DPA consists of two double middeck locker equivalent containers (Vulcan-TP and Vulcan-PDA) plus interconnecting hoses and cables. It will operate in an EXPRESS Rack in the US Lab. It utilizes two 28V, 20 amp inputs, MTL supply and return water, Ethernet and video connections, and a VES/WGS connection from EXPRESS Rack. Vulcan-PDA (Power and Data acquisition) provides the power, data acquisition and control interface, and thermal control for the experiment. Vulcan-TP (Thermophysical Properties) contains the actual experiment, which consists of a vacuum chamber, turbomolecular vacuum pump, vacuum gauge, sample handling system, RF heating system and experiment instrumentation. Vulcan-TP will obtain thermo physical properties data from a set of 18 samples of various elemental metals. These samples will be 4-6 mm in diameter. Each sample will be inserted into the RF coil, which is inside the vacuum chamber, and heated to various temperatures up to and slightly above their melting point. Data will be recorded via video cameras, motion detectors and a pyrometer.

Consortium for Materials Development in Space

Non-linear Optical Materials (NLO) Polymer growth chambers

Hardware Specifications – NLO-PVT (Non-Linear Optics – Physical Vapor Transport

NLO-PVT uses a physical vapor transport process to deposit thin films on a substrate mounted to the growth sting. Growth parameters include the source and sting temperatures that are controlled within $\pm$ 0.05°C, processing time, vacuum and nitrogen purge. It is anticipated that this hardware can be used to grow superior thin films for fabrication of OLEDS. NLO-PVT will use an ISS EXPRESS locker to contain 7 NLO ovens. Each of the cylindrical ovens will contain two Physical Vapor Transport (PVT) cells. Each PVT cell is fitted with electric heaters, which support the vapor transport process. Samples are grown inside of each PVT cell. Maximum temperature is 158°C for the source material and 150°C for the sting. The growth cell is approximately 1.25" in diameter and 2.52" tall. It can accommodate up to a .75 X .75" square substrate or .50" round substrate. A vacuum is required in the sample chamber in order to support the vapor transport process and to provide thermal insulation for the hardware. The NLO-PVT design approach will evacuate each cylinder with the Space Station vacuum system, both the VES and VRS. The heater for each PVT cell is controlled separately, which allows 14 samples to be growing independently. The typical experiment variable is processing time. The NLO-PVT payload plans on initiating 5 cylinders at the same time and then stopping them at different times. The last three cylinders will be started on completion of the first set and completed at the same time. The front panel will be fitted with connectors for power, data, VES, VRS and GN2. There will also be a display for experiment status. No access to the internal components is required. The overall power draw for the payload is not known at this point in time because the system is still in development.

<u>Hardware Specifications – (Non-Linear Optics – Polymer Thin Film Growth)</u>

NLO-PTFG will use a double ISS EXPRESS locker or equivalent housing to contain NLO ultra-violet assemblies. Each of the cylindrical assemblies contains Polymer Thin Film Growth (PTFG) chambers. An UV light mounted in the center of the cylinder polymerizes the samples. Each of the lamps will be turned on and off independently so that processing times for the different groups of samples can vary. All commanding will be preformed from the ground or by an internal controller. The front panel will be fitted with connectors for power and data. There will also be a display for experiment status. No access to the internal components is required. The experiment is still being developed so the overall power draw and final sample configuration is not known at this point in time because we are presently working with a possible commercial partner. The anticipated assembly configuration can be seen in Figure 1.

Space Product Development Experiment Module (SPDEM) furnace module

<u>Hardware Specifications</u>

The PVT side of the payload consists of six PVT ovens each of which house two PVT growth cells. PVT ovens use a physical vapor transport process to deposit thin films on a substrate mounted to the growth sting. Growth parameters include the source and sting temperatures that are controlled within $\pm$ 0.05°C, processing time, vacuum and nitrogen purge. It is anticipated that this hardware can be used to grow superior thin films for fabrication of organic devices. Each of the cylindrical ovens will contain two Physical Vapor Transport (PVT) cells. Each PVT cell is fitted with electric heaters, which support the vapor transport process. Maximum temperature is 158°C for the source material and

150°C for the sting. The growth cell is approximately 1.25” in diameter and 2.52” tall. It can accommodate up to a .75 X .75” square substrate or .50” round substrate. A vacuum is required in the sample chamber in order to support the vapor transport process and to provide thermal insulation for the hardware. The ovens are extremely efficient and require maximum power consumption of 5.5 watts per cell during startup and a steady-state power draw per cell at operating temperature decreases to 3 watts, or 6 watts per oven. Measurements that are taken during the growth process include vacuum levels and temperatures of the source and sting.

Center for Space Power

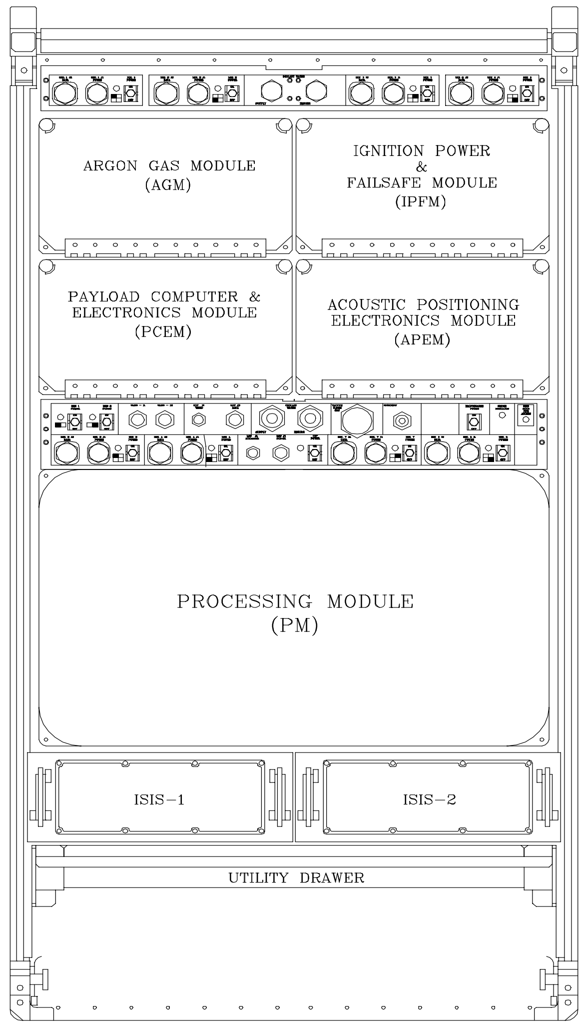
Microencapsulation Electrostatic Processing System (MEPS) drug encapsulation

Hardware Specifications

The Microencapsulation Electrostatic Processing System (MEPS) is an automated apparatus designed to form multi-layered, liquid-filled, microcapsules containing pharmaceuticals.

MEPS is a single locker sized payload that flew and operated successfully on STS-95. MEPS II is a modified rear-air breathing version that is manifested on ISS-UF-1.

The automated processing system has been developed to: 1) form microcapsules in a free-liquid system, wherein the immiscible interface cab be maintained as a planar surface; 2) maintain precise control over solvent flows and fluid shear along the immiscible interface; 3) provide a means for concentrating, flushing, rinsing and harvesting the microcapsules; and 4) provide a means of applying electrostatic fields, to the liquid suspension of microcapsules, for the purpose of depositing ancillary coatings on the outer surface of the microcapsules.



Front layout of the Space-DRUMS™

Figure 2. Space-DRUMS

The Center for Commercial Applications of Combustion in Space – Space-DRUMS, shown in Figure 2, is a furnace that provides containerless high-temperature processing for commercial development efforts in the areas of self-propagating, high-temperature synthesis and exotic glass optical fibers. It will serve as a combustion chamber in microgravity, with the potential capability to perform various kinds of fluid physics research. Space-DRUMS uses a state-of-the art acoustic positioning capability to manipulate samples and keep them from contacting the walls of the processing chamber shown in Figure 3.

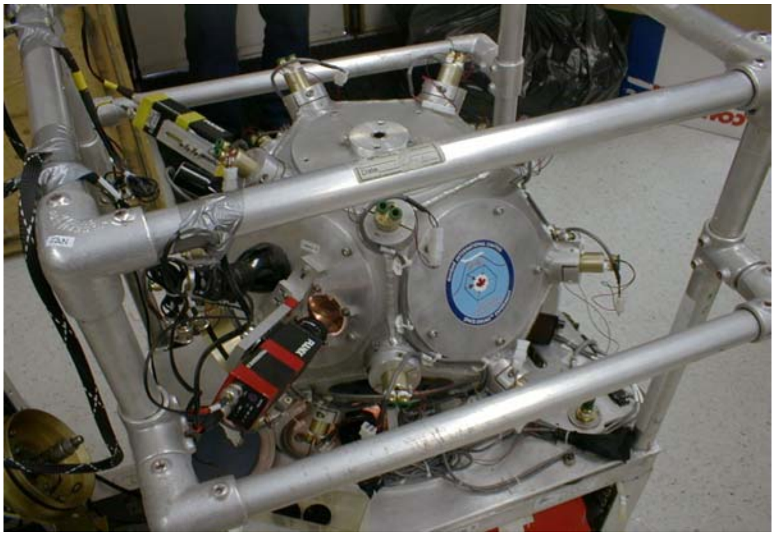


Figure 3. Space-DRUMS - The dodecahedron combustion chamber shown above is the central part of the Space-DRUMS Processing Module. It has 20 ultrasonic transducers attached on the corners and three cameras for internal viewing and recording.

The Center for Biophysical Sciences and Engineering - High Density Protein Crystal Growth and Video Command and Monitoring System is shown in Figure 4. HDPCG will accommodate the growth of 1008 separate, premixed protein crystal growth samples in a single locker. Up to 4 trays of 252 wells can be accommodated into a single-locker NGTC or CRIM. The VCMS has a high resolution video camera for digital imaging and data basing of individual cells. This allows for visual monitoring of crystal growth from the ground.

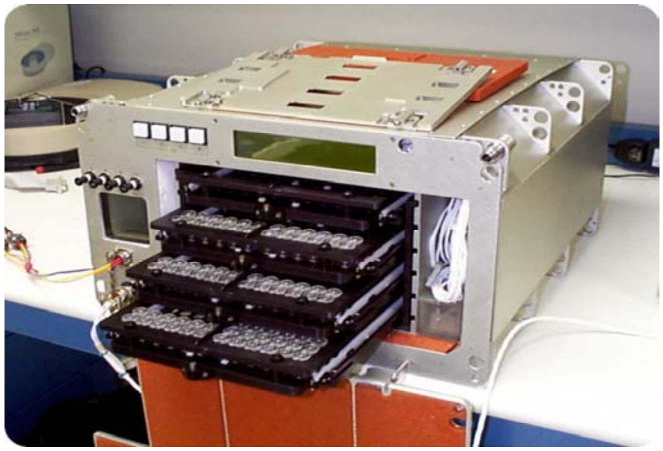
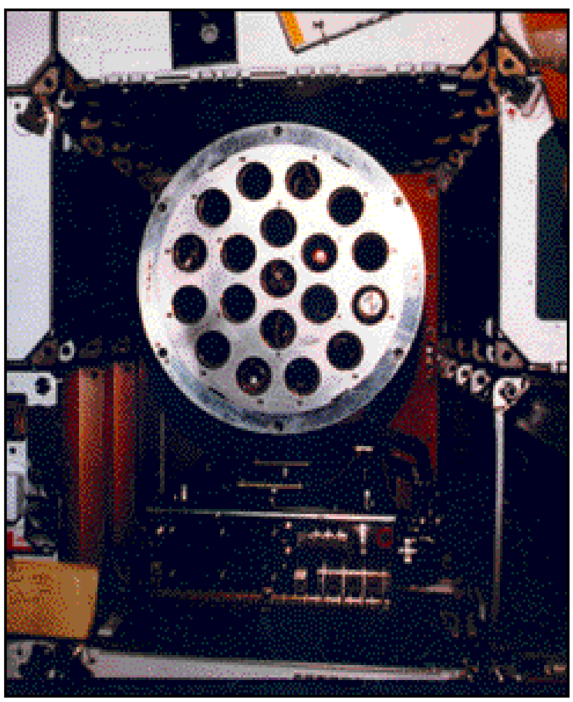


Figure 4 High Density Protein Crystal Growth and Video Command and Monitoring System



Pictured above is the existing ZCG hardware on STS-57 (SpaceHab-01) with the front cover removed.

Figure 5 Zeolite Crystal Growth Furnace

The Center for Advanced Microgravity Materials Processing Crystal Growth Furnace is shown in Figure 5. This combination of furnaces will facilitate a temperature-controlled, solution crystal growth process for Space Station that will allow researchers to grow larger zeolite/zeo-type crystals with fewer defects for applications in catalysis and electronic materials. One existing furnace, that has flown on three shuttle missions, will be joined by three new furnace modules, providing enhanced capabilities.

Summary

The Commercial Space Centers have developed more than 14 space qualified experiment packages in partnership with their consortium members. This hardware can be used to carryout experiments ranging from crystal growth and combustion at high temperature to plant and animal investigations. The centers are continuously seeking new partners to join their consortia in developing new flight hardware or extending the use of existing experimental capabilities. Interested organizations are encouraged to contact the center of their choice.